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Research Article

MHD Stagnation Point Flow over a Stretching/Shrinking Sheet in Nanofluid with Suction Effect

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ABSTRACT

The effect of suction on magnetohydrodynamics (MHD) stagnation point flow of a nanofluid towards a linearly stretching/shrinking sheet at the boundary was investigated. The water-based nanofluids containing three metallic nanoparticles namely, copper (Cu), alumina (Al_2O_3) and titania (TiO_2) are considered. By using a similarity transformation, the governing nonlinear partial differential equations (PDEs) subjected to the boundary conditions are converted into the system of ordinary differential equations (ODEs). Numerical results are obtained using the boundary value problem solver bvp4c in MATLAB software. The investigation focuses on the impact of suction parameters and the nanoparticle volume fraction parameter on the nanofluids with Prandtl number, $Pr = 6.2$. The graphical representation and analysis of the influence of the suction parameter S and the magnetic parameter M on the skin friction coefficient, local Nusselt number are provided. Both velocity and temperature profiles are presented to show the duality of the solution. The numerical results of both velocity and temperature profiles including the skin friction coefficient and local Nusselt number are presented for various values of the governing parameters. The results show that the temperature and velocity profiles are influenced by suction, magnetic field, and nanoparticle volume fraction. The finding suggests that incorporating nanoparticles into the based fluids leads to an increase in both the skin friction coefficient and the heat transfer rate at the surface.

Keywords: Magnetohydrodynamics, stagnation point flow, nanofluids, suction, stretching, shrinking sheet

1. INTRODUCTION

Nanofluids, which consist of nanoparticles dispersed in a base fluid, have gained attention as a potential means to improve thermal conductivity. As a result, they have found uses in many sectors. Magnetohydrodynamics (MHD) is a field of study that examines the movement and behavior of fluids that may conduct electricity, such as plasmas, liquid metals, and electrolytes. MHD stagnation point flow in nanofluids with suction over a stretching/shrinking sheet can optimize heat transfer processes in many industries such as electronics cooling, aerospace engineering, biomedical applications, materials processing and manufacturing by improving efficiency, performance, and sustainability in engineering and technology. The study of stagnation point flow with stretching or shrinking sheets in viscous fluids has been extensively researched. Hiemenz (1911) was the first to offer an accurate solution for the steady two-dimensional stagnation point flow towards a stationary semi-infinite wall; Homann (1935) later expanded this analysis to axisymmetric instances. Further research by Mahapatra and Gupta (2001; 2003) concentrated on heat transfer in magnetohydrodynamic (MHD) stagnation-point flows over stretched surfaces. Wang (2008) developed the notion of flow past a shrinking sheet, which yielded unique and dual solutions for various parameters. The use of nanofluids, which comprise nanosized particles spread in a base fluid, broadened the scope of these research. Bachok et al. (2013) investigated the behaviour of such flows, revealing non-unique solutions for shrinking sheets but unique solutions for stretching sheets. Choi (1995) and Masuda et al. (1993) revealed that nanofluids had higher thermal conductivity, which led to a broad adoption of the notion. Furthermore, researchers such as Rashidi et al. (2013), Sandeep and Sulochana (2015), Ishak et al. (2009), and Mahapatra and Gupta (2001; 2003) have included magnetohydrodynamic effects in these analyses, investigating their impact on stagnation-point flows over stretching and shrinking sheets.

Two popular models, the Tiwari-Das model (2007) and the Buongiorno model (2006), have been used to investigate nanofluid behaviour. The former evaluates the volume fraction of nanoparticles, whereas the later takes into account Brownian motion and thermophoresis effects. Researchers have used these models to examine a variety of phenomena, including blood flow, boundary layer flow via varied geometries, and the effect of non-Newtonian behaviour. In addition to stretching sheets, research into shrinking sheets has gained traction, showing novel flow properties such as unconfined vorticity and the need for suction at the border for stable flow. This field has attracted a large number of researchers, who have helped to advance our understanding of boundary layer fluxes and its applications in a variety of industrial processes. As a whole, research in this topic is evolving, encouraged by the discovery of new fluid types, the study of additional physical factors, and the use of advanced mathematical models to better explain and predict flow behaviour.

Rashidi et al. (2014) applied homotopy analysis method HAM to investigate the free convective heat and mass transfer of a steady two-dimensional magnetohydrodynamic (MHD) fluid flow in porous medium. Whereas the effect of magnetohydrodynamic (MHD) on boundary layer flow towards an exponentially shrinking permeable sheet with slip condition saturated in porous medium was investigated by Jain and Choudhary (2015). Hsu et al. (2019) studied the effect of suction on a boundary layer flow of a magnetohydrodynamic fluid over a shrinking sheet. The research conducted by Sharma et al. (2014), Mansur et al. (2015), Anwar et al. (2017), Kamal et al. (2019), Jaafar et al. (2022) and Bachok et al. (2023) collectively provide significant insights into magnetohydrodynamics (MHD) stagnation-point flow over stretching/shrinking sheets immersed in nanofluids with suction effects. Nanoparticles improve the skin friction coefficient and local Nusselt number, whereas magnetic fields boost the coefficient and broaden the solution domain range. Suction parameters delay the boundary layers, whereas injection factors influence skin friction, temperature profile, and boundary layer thickness. Nonlinear factors increase flow separation and necessitate stability assessment. The influence of magnetohydrodynamics (MHD) on boundary layer stagnation point flow over a nonlinear stretching/shrinking surface in hybrid carbon nanotubes with Response Surface Methodology (RSM) has been discussed by Samat et al. (2024).

This article is an extension of the research by Ibrahim et al. (2013) and is motivated by the studies mentioned previously. It analyses the magnetohydrodynamic (MHD) stagnation point flow of a nanofluid across a stretching/shrinking sheet with suction action at the boundary. MHD studies the dynamics of electrically conducting fluids, including plasmas, liquid metals, and electrolytes. The present research is primarily concerned with the relationship between the governing parameters such as skin friction coefficient and the local Nusselt number with the parameters stretching/shrinking, magnetic velocity ratio, Brownian motion, and thermophoresis. Numerical solutions are shown graphically and in tabular form to demonstrate how these factors affect the skin friction coefficient and the local Nusselt number.

2. MATHEMATICAL FORMULATION

Consider a scenario involving a steady, incompressible nanofluid within the region where > 0 . The flow is driven by a permeable stretching/shrinking surface located at $y = 0$, close to the stagnation point at $x = 0$. This configuration is depicted in Figure 1, where x and y represent the Cartesian coordinates along and normal to the surface, respectively. The velocity of the stretching/shrinking sheet is denoted as $U_w = ax$, and the ambient fluid velocity, U_∞ , varies linearly from the stagnation point with bx, where a and b are positive constants. The nature of the stretching or shrinking sheet is determined by the conditions of $a > 0$ and $a < 0$, respectively. Moreover, a perpendicular transverse magnetic field with a constant electrical conductivity σ, denoted as B_0, is applied to the sheet. The influence of the induced magnetic field is disregarded due to its negligible magnitude relative to the small magnetic Reynolds number.

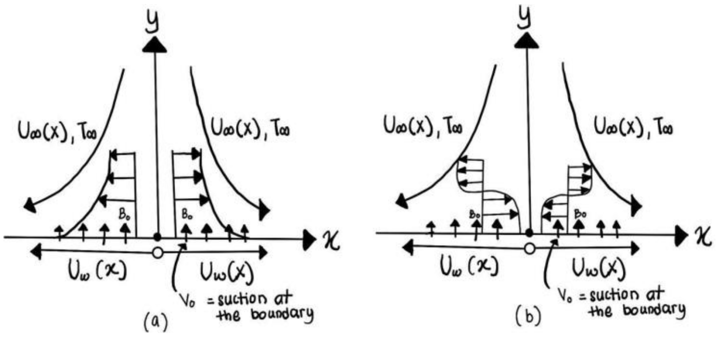

Figure 1. Mathematical model of the problem

We consider the continuous two-dimensional MHD governing equations for a laminar nanofluid containing different types of nanoparticles like Cu, l_{23} and i_2 with suction as follows according to Ahmad et al. (2011):

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{1}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = U_\infty \frac{dU_\infty}{dx} + \frac{\mu_{nf}}{\rho_{nf}}\frac{\partial^2 u}{\partial y^2} + \frac{\sigma B_0^2}{\rho_{nf}}(U_\infty - u) \tag{2}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha_{nf}\frac{\partial^2 T}{\partial y^2}, \tag{3}$$

The equations are subjected to the boundary conditions

$$u = U_w(x), \quad v = v_0, \quad T = T_w \quad \text{at } y = 0,$$
$$u \to U_\infty(x), \quad T \to T_w \quad \text{as } y \to \infty. \tag{4}$$

where u and v are the velocity components along the x and y-axes, respectively. While μ_{nf} denotes the viscosity of the nanofluid, ρ_{nf} denotes nanofluid density, α_{nf} denotes nanofluid thermal diffusivity and T is the nanofluid temperature according to Oztop and Abu Nada (2008).

$$\rho_{nf} = (1-\varphi)\rho_f + \varphi\rho_s,$$

$$\alpha_{nf} = \frac{k_{nf}}{\left(\rho C_p\right)_{nf}},$$

$$\frac{k_{nf}}{k_f} = \frac{\left(k_s + 2k_f\right) - 2\varphi\left(k_f - k_s\right)}{\left(k_s + 2k_f\right) + \varphi\left(k_f - k_s\right)},$$

$$\mu_{nf} = \frac{\mu_f}{(1-\varphi)^{2.5}},$$

$$\left(\rho C_p\right)_{nf} = (1-\varphi)\left(\rho C_p\right)_f + \varphi\left(\rho C_p\right)_s. \quad (5)$$

In order to transform equations (1) - (3) into the governing system of ordinary differential equations subjected to the boundary equations (4), we introduce the following similarity transformation variables given by Bachok et al. (2013).

$$\eta = \left(\frac{b}{\nu_f}\right)^{\frac{1}{2}} y, \ \ \psi = \left(\nu_f b\right)^{\frac{1}{2}} x f(\eta), \qquad \theta = \frac{T - T_\infty}{T_w - T_\infty} \quad (6)$$

where T_w is the fluid temperature at the stretching/shrinking sheet. The fluid temperature, that is far away from the stretching/shrinking surface is denoted as T_∞. The transformed ordinary differential equations are obtained by substituting variables (6) into (2) - (3):

$$\frac{1}{(1-\varphi)^{2.5}\left(1-\varphi+\frac{\varphi\rho_s}{\rho_f}\right)} f''' + ff'' - f'^2 + 1 + M(1-f') = 0, \quad (7)$$

$$\frac{1}{Pr}\frac{\frac{k_{nf}}{k_f}}{\left(1-\varphi+\varphi\left(\rho C_\rho\right)_s/\left(\rho C_\rho\right)_f\right)}\theta'' + f\theta' = 0. \quad (8)$$

subjected to the boundary conditions (4) become

$$f(0) = S, \ \ f'(0) = \varepsilon, \quad \theta(0) = 1,$$

$$f'(\eta) \to 1, \ \ \theta(\eta) \to 0 \text{ as } \eta \to \infty. \quad (9)$$

where parameter ε is defined as $\varepsilon = \frac{a}{b}$. Here, Pr, M and S are the Prandtl number, magnetic, and mass transfer parameters, respectively. In this problem, we only consider the effect of suction, where $S > 0$. The physical quantities of our interest for this study are the skin friction coefficient C_f, and the local Nusselt number Nu_x , which are defined as

$$C_f = \frac{\tau_w}{\rho_f U_\infty^2}, \ \ Nu_x = \frac{x q_x}{k_f (T_w - T_\infty)} \quad (10)$$

where τ_w is the skin friction or shear stress along the plate and q_w is the heat flux from the plate, which are defined as:

$$\tau_w = \mu_{nf}\left(\frac{\partial u}{\partial y}\right)_{y=0}, \quad q_w = -k_{nf}\left(\frac{\partial T}{\partial y}\right)_{y=0} \tag{11}$$

Hence, by using the similarity variable (6), we get

$$C_f Re_x^{\frac{1}{2}} = \frac{1}{(1-\varphi)^{2.5}} f''(0), \quad \frac{Nu_x}{Re_x^{1/2}} = -\frac{k_{nf}}{k_f}\theta'(0) \tag{12}$$

where $Re_x = \frac{U_\infty x}{\nu_f}$ is the Reynolds number.

3. RESULTS AND DISCUSSION

The governing system of ordinary differential equations (7) and (8) subject to the boundary conditions (9) are solved numerically by using bvp4c function in MATLAB software. Consequently, the MATLAB programmer will be utilised for commercial purposes to get numerical outcomes. Thus, we will obtain the velocity and temperature profiles with various values of magnetic parameter M, suction parameter S, Prandtl number Pr, stretching/shrinking parameter ε and nanoparticle volume fraction parameter of the nanofluid φ. As shown in Tables 1-2, the present results of the skin friction coefficient $C_f Re_x^{1/2}$ and the local Nusselt number $Nu_x Re_x^{-1/2}$ are compared to those of previous studies by Bachok et al. (2011) and Abd Rahman et al. (2019) for the case when the value of magnetic field and suction are zero to assess the accuracy of the present code and validate present results. This comparison reveals that the present results are in good comparison with the previous studies. Therefore, we are certain that the numerical results are correct. Table 3 represents the thermophysical properties of nanoparticles and water according to Oztop and Abu-Nada (2008).

Table 1. Comparison of the skin friction coefficient of *Cu*-water

ε	φ	**Bachok et al. (2011)**	**Abd Rahman et al. (2019)**	**Present Results**
-0.5	0.1	2.2865	2.286511	2.286512
	0.2	3.1826	3.182538	3.182538
0	0.1	1.8843	1.884324	1.884324
	0.2	2.6226	2.622743	2.622743
0.5	0.1	1.0904	1.090453	1.090453
	0.2	1.5177	1.517774	1.517774

Table 2. Comparison of the local Nusselt number for *Cu*-water

ε	φ	**Bachok et al. (2011)**	**Abd Rahman et al. (2019)**	**Present Results**
-0.5	0.1	0.8385	0.838510196	0.838510196
	0.2	1.0802	1.080308024	1.080308024
0	0.1	1.4043	1.404327133	1.404327133
	0.2	1.6692	1.669337652	1.669337652
0.5	0.1	1.8724	1.872386446	1.872386446
	0.2	2.1577	2.157690310	2.157690310

Table 3. Thermophysical properties of fluid and nanoparticles

Physical properties	**Fluid phase (water)**	**Cu**	$\mathbf{Al_2O_3}$	$\mathbf{TiO_2}$
(/*g*)	4179	385	765	686.2
($g/^3$)	997.1	8933	3970	4250
(/)	0.613	400	40	8.9538

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Figures 2 and 3 illustrates the effect of suction on the skin friction coefficient $f''(0)$ and local Nusselt number $-\theta'(0)$ with magnetic field M and nanoparticle volume fraction in response to the stretching/shrinking sheet. From the figures, both the skin friction coefficient and the local Nusselt number increase as suction parameter S increases. The figures show that the dual solution exist in the region $\varepsilon_c < \varepsilon \leq -1$, whereas unique solution for $\varepsilon \geq -1$ and no solution exist for $\varepsilon < \varepsilon_c < 0$. According to our calculation, the results show that the critical values, ε_c are -1.3350001, -1.490004 and -1.670004 for $S = 0, 0.25$ and 0.5 respectively. As S rises, both $f''(0)$ and $-\theta'(0)$ increase, suggesting improved heat transmission flowing to thinner thermal boundary layers.

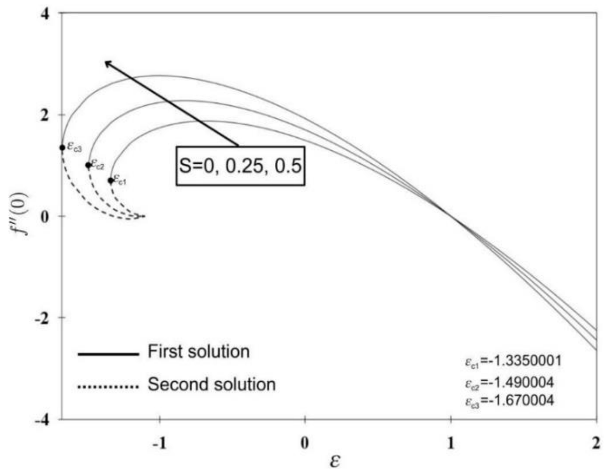

Figure 2. Variation of f"(0) with ε for some values of S, $\varphi = 0.1$ of *Cu*-water working fluid, $Pr = 6.2$ and $M = 0.1$

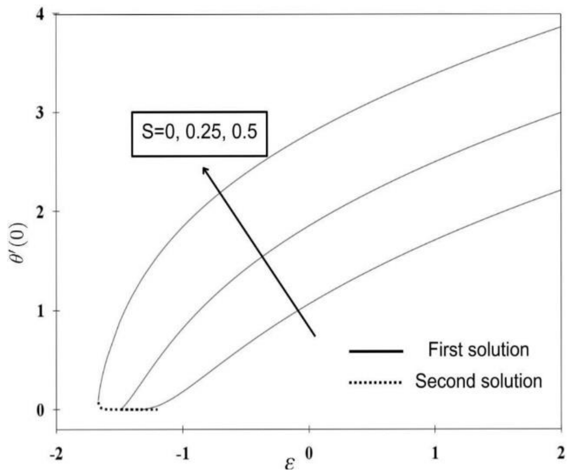

Figure 3. Variation of $-\theta'(0)$ with ε for some values of S, φ = 0.1 of *Cu*-water working fluid, $Pr = 6.2$ and $M = 0.1$

Figures 4 and 5 show the effect of the magnetic field parameter M on $f''(0)$ and $-\theta'(0)$ under the identical fluid conditions with S = 0.25. Increasing M results in larger $f''(0)$ and $-\theta'(0)$, indicating improved flow separation and heat transfer rates. The presence of a magnetic field induces Lorenz forces which cause the force on the velocity field. Subsequently, the effect of the magnetic field accelerates the separation of the boundary layer.

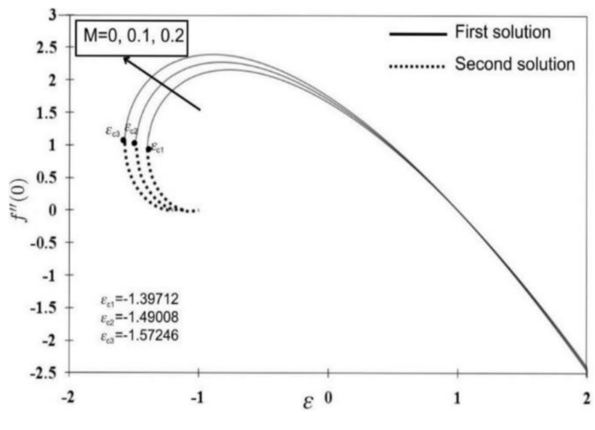

Figure 4. Variation of f"(0) with ε for some values of M for *Cu*-water working fluid, $Pr = 6.2, S = 0.25$ and $\varphi = 0.1$

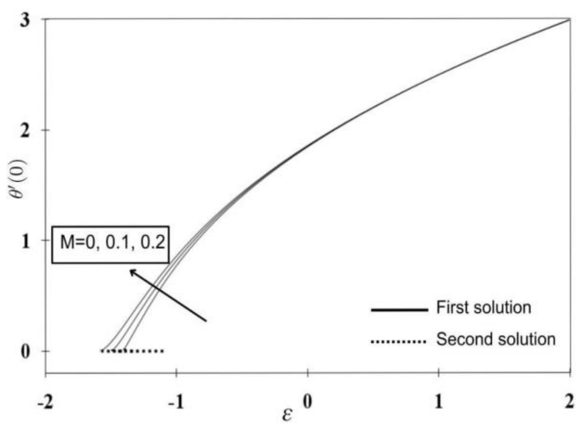

Figure 5. Variation of $-\theta'(0)$ with ε for some values of M for *Cu*-water working fluid, $Pr = 6.2, S = 0.25$ and $\varphi = 0.1$

Velocity and temperature profiles for different values of suction parameters can be seen in Figures 6 and 7. From the figures, it is noticed that the dual solutions exist for the case of shrinking sheet. For the first solution, it is clear that the velocity is increasing, and the temperature decreases as the suction parameter increases. By imposing the suction parameter has caused to the reduction in momentum boundary layer thickness and thus increases the flow velocity near the surface. It is also observed from Figure 7 that the thermal boundary layer is reduced for higher values of the suction parameters and hence decreases the temperature near the surface for the first solution. However, the opposite trend can be seen for the second solution.

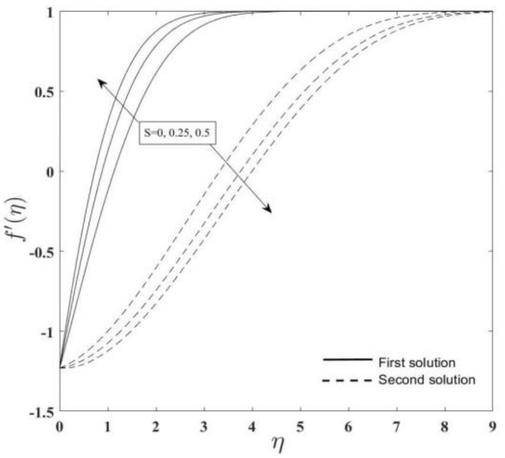

Figure 6. Velocity profiles for some values of S for Cu-water working fluid with $\varepsilon = -1.2$, $Pr = 6.2$ and $M = 0.1$ and $\varphi = 0.2$

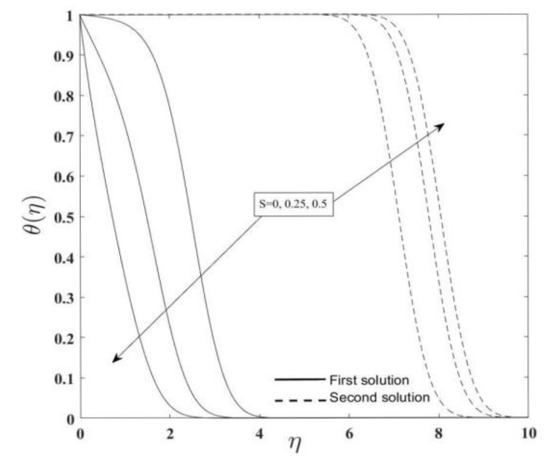

Figure 7. Temperature profiles for some values of S for Cu-water working fluid with $\varepsilon = -1.2$, $Pr = 6.2$ and $M = 0.1$ and $\varphi = 0.2$

The variation of skin friction coefficient and local Nusselt number for different nanoparticles and suction parameter S with $M = 0.1$ are shown in Figures 8 and 9. The figures show a roughly linear relationship between the nanoparticle volume fraction parameters and the various values of suction parameters. It is observed that the skin friction coefficient is highest for nanoparticle Cu (nanoparticle with high density), followed by Al_2O_3 and TiO_2. The presence of nanoparticles in the fluids significantly improves the effective thermal conductivity, hence improve the heat properties of the fluid as seen in Figure 9.

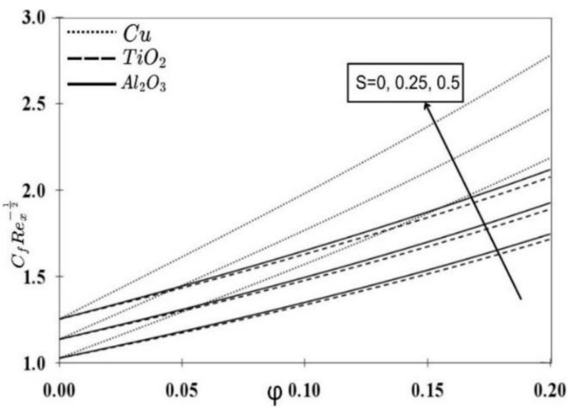

Figure 8. Variation of skin friction coefficient $C_f Re_x^{1/2}$ for different nanoparticles and suction parameter S with $\varepsilon = 1.5, Pr = 6.2$ and $M = 0.1$

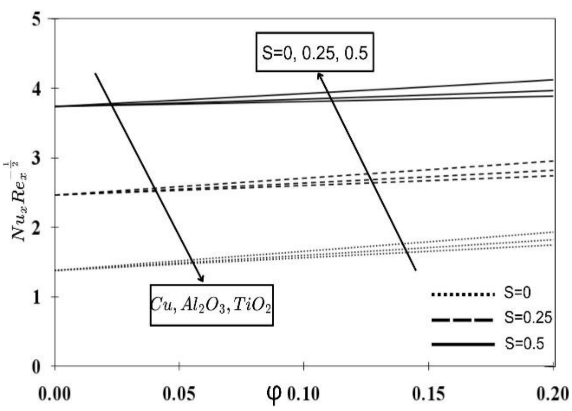

Figure 9. Variation of local Nusselt number $Nu_x Re_x^{-1/2}$ for different nanoparticles and suction parameter S with $\varepsilon = 1.5, Pr = 6.2$ and $M = 0.1$

Figures 10 and 11 display the variation of skin friction coefficient and the local Nusselt number for different nanoparticles with different values of magnetic field M. Based on Figure 10, it shows that the skin friction coefficient is highest for nanoparticle Cu, followed by TiO_2 and Al_2O_3. Meanwhile, the local Nusselt number is largest for Cu, followed by Al_2O_3 and TiO_2 (nanoparticle with low thermal conductivity) as seen in Figure 11. According to the figures, it can be concluded that an increase in the magnetic field parameter M will increase both the skin friction coefficient and the local Nusselt number.

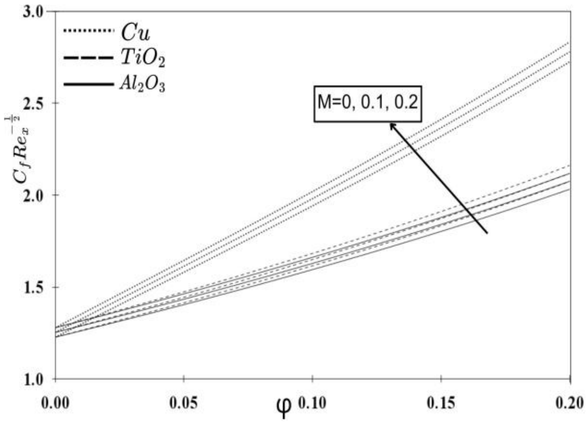

Figure 10. Variation of skin friction coefficient $C_f Re_x^{1/2}$ for different nanoparticles and magnetic field M with $\varepsilon = 1.5, Pr = 6.2$ and $S = 0.5$

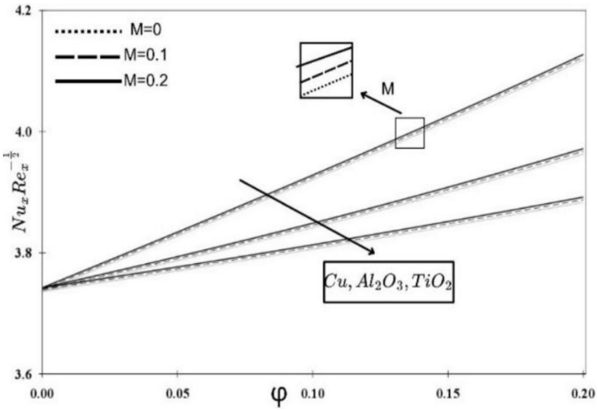

Figure 11. Variation of local Nusselt number $Nu_x Re_x^{-1/2}$ for different nanoparticles and magnetic field M with $\varepsilon = 1.5, Pr = 6.2$ and $S = 0.5$

4. CONCLUSION

The effect of suction on magnetohydrodynamics (MHD) stagnation point flow of a nanofluids is observed towards a stretching/ shrinking sheet. Numerical results for several ranges of parameters which are suction parameters, magnetic parameter, velocity ratio parameter, stretching/shrinking parameter, nanoparticles volume fraction parameters were obtained using bvp4c in MATLAB software. The behaviour of the flow and the heat transfer characteristics for three types of nanoparticles considered in this study which are copper (Cu), alumina (Al_2O_3) and titania (TiO_2) were solved numerically in water-based fluid with Prandtl number $Pr = 6.2$. Both the skin friction coefficient and heat transfer rate rise as the suction parameter S does. The skin friction coefficient and heat transfer rate both rise as the magnetic field parameter M does. The results discovered that there is a unique solution for the stretched sheet, whereas there are two possibilities of solutions for the shrinking sheet. When the magnetic field is present and the suction effect at the boundary rises, the range of the solution to exist also increases. Furthermore, an increase in suction and the magnetic effect result in a rise in the skin friction coefficient.

Conflict of Interest

The authors declare no conflicts of interest.

Author Contribution Statement

Nurain Naziha Alias: Writing - original draft, methodology, software, visualization. Haliza Rosali: Conceptualization, writing - review and editing, methodology - review and editing, supervision. Norfifah Bachok@Lati: writing – review and editing.

Data Availability Statement

The data that support the findings of this study are openly available at doi: 10.1186/1556-276X-6-623 and doi: 10.13189/ujme.2019.070406

REFERENCES

Abd Rahman NH, Bachok N, Rosali H. (2019). Magnetohydrodynamics stagnation-point flow over a stretching/shrinking sheet in nanofluids. *Universal Journal of Mechanical Engineering,* 7(4), 183-191.

Ahmad S, Rohni AM, Pop I. (2011). Blasius and sakiadis problems in nanofluids. *Acta Mechanica*, 218, 195-204.

Anwar MI, Shafie S, Hayat T, Shehzad SA, Salleh MZ. (2017). Numerical study for MHD stagnation-point flow of a micropolar nanofluid towards a stretching sheet. *Journal of the Brazilian Society of Mechanical Sciences and Engineering,* 39, 89-100.

Bachok N, Ishak A, Nazar R, Senu N. (2013). Stagnation-point flow over a permeable stretching/shrinking sheet in a copper-water nanofluid. *Boundary value problems*, 1, 1-10.

Bachok N, Ishak A, Pop I. (2011). Stagnation-point flow over a stretching/shrinking sheet in a nanofluid. *Nanoscale Research Letters*, 6, 1-10.

Bachok N, Tajuddin SNN, Anuar NS, Rosali H. (2023). Numerical computation of stagnation point flow and heat transfer over a nonlinear stretching/shrinking sheet in hybrid nanofluid with suction/injection effects. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences,* 107(1), 80-86.

Buongiorno J. (2006). Convective transport in nanofluids. *Journal of Heat Transfer*, 128, 240-250.

Choi S. (1995). Enhancing thermal conductivity of fluids with nanoparticles. *ASME Fluids Engineering Division*, 231, 99-105.

Hiemenz K. (1911). Die Grenzschicht an einem in den gleichförmigen Flüssigkeitsstrom eingetauchten geraden Kreiszylinder. *Dinglers Polytechnisches Journal*, 326, 321-324.

Homann F. (1936). Der Einfluss grosser Zahigkeit bei der Stromung um den Zylinder und um die Kugel. *Zeitschrift fur Angewandte Mathematik und Mechanik*, 16, 153-164.

Hsu CH, Tsai TH, Chang CC, Huang WH. (2019). A boundary layer flow analysis of a magnetohydrodynamic fluid over a shrinking sheet. *Advances in Mechanical Engineering*, 11(3), 1-12.

Ibrahim W, Shankar B, Nandeppanavar MM. (2013). MHD stagnation point flow and heat transfer due to nanofluid towards a stretching sheet. *International Journal of Heat and Mass Transfer*, 56(1-2), 1-9.

Ishak A, Jafar K, Nazar R, Pop I. (2009). MHD stagnation-point flow towards a stretching sheet. *Physic A*, 388, 3377-3383.

Jaafar A, Waini I, Jamaludin A, Nazar R, Pop I. (2022). Magnetohydrodynamics flow and heat transfer of a hybrid nanofluid past a nonlinear surface stretching/shrinking with effects of thermal radiation and suction. *Chinese Journal of Physics*, 79, 13-27.

Jain S,Choudhary R. (2015). Effects of MHD on boundary layer flow in porous medium due to exponentially shrinking sheet with slip. *Procedia Engineering*, 127, 1203-1210.

Kamal F, Zaimi K, Ishak A, Pop I. (2019). Stability analysis of MHD stagnation-point flow towards a permeable stretching/shrinking sheet in a nanofluid with chemical reactions effect. *Sains Malaysiana*, 48(1), 243-250.

Mahapatra TR, Gupta AS (2001). Magnetohydrodynamic stagnation-point flow towards a stretching sheet. *Acta Mechanica*, Vol.152, 191-196.

Mahapatra TR, Gupta, AS (2003). Stagnation-point flow towards a stretching surface. *Canadian Journal of Chemical Engineering*, 81, 258-263.

Mansur S, Ishak A, Pop I. (2015). The magnetohydrodynamic stagnation point flow of a nanofluid over a stretching/shrinking sheet with suction. *Plos One*, 10, 1-14.

Masuda H, Ebata AKT, Hishinuma N. (1993). Alteration of thermal conductivity and viscosity of liquid by dispersing ultra-fine particles. *Netsu Bussei*, 4(4), 227-233.

Oztop HF, Abu-Nada E. (2008). Numerical study of natural convection in partially heated rectangular enclosures filled with nanofluids. *International Journal of Heat and Fluid Flow*, 29(5), 1326-1336.

Rashidi MM, Ibrahim B, Shankar W, Nandeppanavar MM. (2013). MHD stagnation point flow and heat transfer due to nanofluid towards a stretching sheet. *International Journal of Heat and Mass Transfer*, 56, 1-9.

Rashidi MM, Rostami N, Freidoonimehr S, Abbasbandy. (2014). Free convective heat and mass transfer for MHD fluid flow over a permeable vertical stretching sheet in the presence of the radiation and buoyancy effects, *Ain Shams Engineering Journal*, 5, 901-912.

Samat NAA, Bachok N, Arifin NM. (2024). Boundary layer stagnation point flow and heat transfer over a nonlinear stretching/shrinking sheet in hybrid carbon nanotubes: numerical analysis and response surface methodology under the influence of magnetohydrodynamics. *Computation*, 12(46), 1-29.

Sandeep N, Sulochana C. (2015). Dual solutions for unsteady mixed convection flow of MHD micropolar fluid over a stretching/shrinking sheet with non-uniform heat source/sink. *Engineering Science and Technology, an International Journal*, 18, 738-745.

Sharma R, Ishak A, Pop I. (2014). Stability analysis of magnetohydrodynamic stagnation-point flow toward a stretching/shrinking sheet. *Computers Fluids*, 102, 94-98.

Tiwari RK, Das MK (2007). Heat transfer augmentation in a two-sided lid-driven differentially heated square cavity utilizing nanofluids. *International Journal of Heat and Mass Transfer*, 50, 2002-2018.

Wang CY. (2008). Stagnation flow towards a shrinking sheet. *International Journal of Non-Linear Mechanics*, 43, 377-382.